



Characterization and comparison of the copper-base metallurgy of the Harappan sites at Farmana in Haryana and Kuntasi in Gujarat, India



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ABSTRACT

Copper-base metallic artifacts excavated from two Indus settlements at Farmana in Haryana and Kuntasi in Gujarat, India, were examined for their microstructure and chemical composition. The two sites were approximately contemporaneous and belong to the mature Harappan phase of the Indus Civilization, spanning the second half of the 3rd millennium BC. The microstructural data revealed that almost every object examined was substantially worked during fabrication. The composition data showed that arsenic served as the single alloying element in about 60% of the Farmana artifacts, with the rest of them made of either unalloyed copper or brass. Tin was not added deliberately in any of the Farmana artifacts. In the Kuntasi assemblage, however, tin as well as arsenic played a key role and most artifacts were alloyed with either arsenic or tin or both. Nevertheless, the two Harappan sites seem to have established a similar technology based on forging as the key fabrication method and circulation of product intermediaries as the primary means for metal acquisition. This article will present a detailed account of the mentioned results to characterize the technological status achieved by the two Indus communities. The results will then be compared with those of other Indus sites to gain insight into factors representing the general Indus bronze tradition.

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1. Introduction

Copper seems to have made its first appearance in the greater Indus region during the early phase of human adaptations, termed the Early Food Processing Era (ca. 6500–5000 BC). Since then copper and its alloys remained the dominant metallic materials throughout the following Indus period, which is divided into the Regionalization (ca. 5000–2600 BC), Integration (2600–1900 BC) and Localization (1900–1300 BC) Eras, until the advent of the Iron Age (Kenoyer and Miller, 1999). The Harappan Phase (ca. 2600–1600 BC), representing the Integration Era of the Indus Civilization, is particularly notable for the extensive use of copper-base materials. This fact is clearly seen in the numerous metallic objects of copper and its alloys thus far excavated from various Indus sites of this period. The progress in copper-base metallurgy during this specific period, which is also named the Mature Harappan Phase to distinguish it from the Early (ca. 3300–2600 BC)

and Late (ca. 1900–1300 BC) Harappan Phases, has special significance as it accompanied the establishment of the first urban societies in southern Asia. The excavated metallic artifacts, therefore, may serve as key archaeological materials from which valuable information can be drawn for a better assessment of the cultural and natural environments surrounding the Indus communities.

Kenoyer and Miller (1999) are one of those who, in an effort to test this possibility, collected data available on the chemical composition of copper alloys from the mature Harappan phase sites of Mohenjo-Daro, Harappa, Lothal and Rangpur (Fig. 1). Their data, which will serve as an invaluable reference in the discussion of our analytical results, need to be briefly reviewed for our specific purpose. Of the 129 objects referred to, approximately 40% were made of alloys containing either tin or arsenic or both while the remaining 60% were made of copper metals with their tin and arsenic contents being too low (less than 1.0%) to be considered a result of deliberate alloying. The composition of the alloyed objects shows substantial variations from 1.0% to 13.8% for tin contents and from 1.0% to 6.58% for arsenic contents. Lead was used only in exceptional cases. No evidence of deliberate zinc alloying is found in any of those reported. Surprisingly, the objects made of arsenical copper came exclusively from the sites at Mohenjo-Daro and

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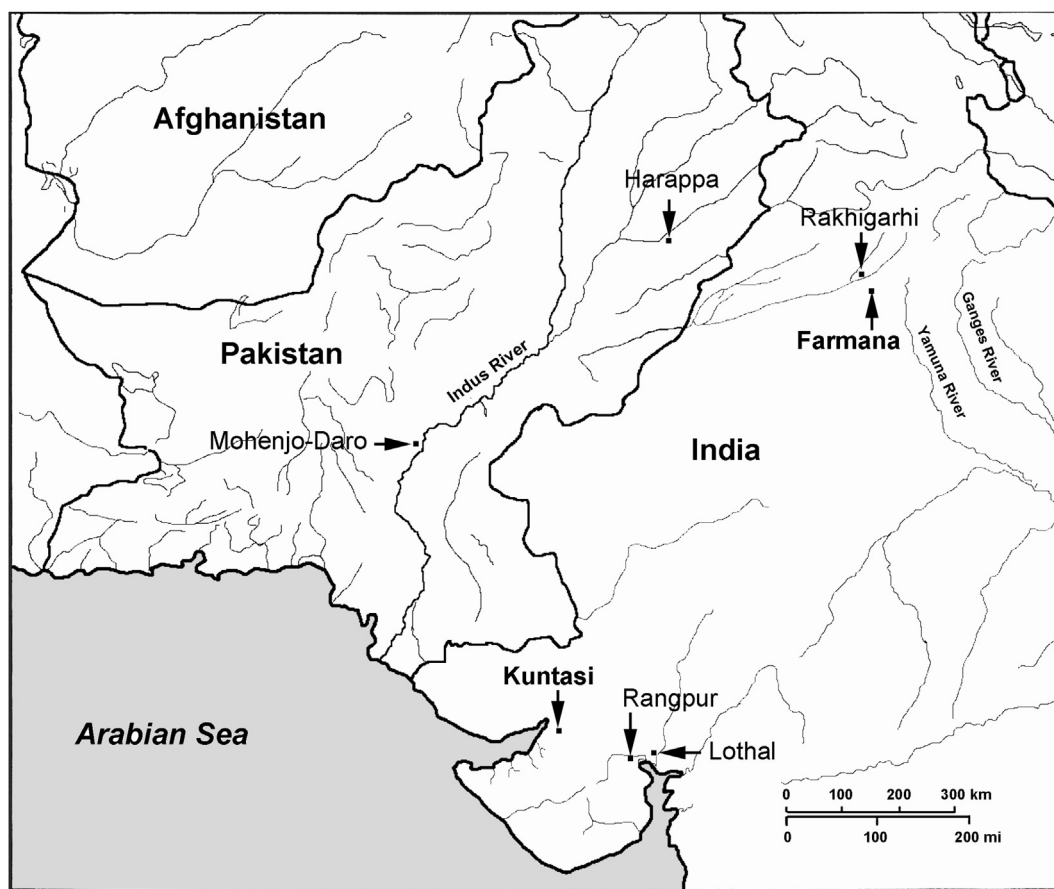


Fig. 1. Map of the greater Indus region showing the locations of the Farmana and Kuntasi sites from which the bronze objects examined were excavated, along with other important Indus sites.

Harappa while no arsenic at all was detected in any of those from the sites at Lothal and Rangpur, located in the current Indian territory of Gujarat.

Despite the ambiguities addressed by Kenoyer and Miller (1999: 114) themselves, the above data reveal a few factors of significance about the Indus metallurgical tradition during the Harappan phase. First of all, the metalworkers were aware of the beneficial effect of tin and arsenic as alloying elements. Nevertheless, it seems they were unable to practice this knowledge in the majority of the cases reported, perhaps because access to tin and arsenic was limited. Another aspect to note is the total absence of arsenic in objects from the two Indian sites at Gujarat. This difference suggests the existence of regional variations in the availability of technological or material resources. The valuable information derived from the data sets as depicted above convinced us that it is necessary to do more analytical work on copper-base artifacts with reliable and diverse contexts in chronology and provenance. We decided to begin by focusing on the Indus objects excavated from the two Harappan sites at Farmana in Haryana and Kuntasi in Gujarat.

Our main objective is to characterize the metallurgical traditions of the two regions in terms of alloy composition and fabrication technique. We will pay special attention to the examination of microstructures, which is necessary to infer the thermo-mechanical treatments applied during fabrication. Microstructural examination provides an important tool for detecting a wide range of non-uniformities present in test specimens. The resulting information, which cannot be obtained with any other techniques, enhances the reliability of composition analyses and enables unusual treatments, if any, applied to a given artifact to be

determined. An example of success in this line of research is given by Park and Shinde (2013) who proposed the possibility of bronze bangles from the Indian megalithic sites to serve as intermediaries for trade or further processing. The composition and microstructural data obtained will then be compared and contrasted to check if there was any variation in the technological status achieved by the two Indus communities. We will also review the composition data compiled by Kenoyer and Miller (1999) relative to ours.

2. Comments on sites

The site at Farmana (Fig. 1) is located in the Haryana state, approximately 60 km northeast of Delhi. It was excavated by the India-Japan collaborative expedition under the project entitled 'Indus Project' between 2006 and 2008 (Shinde et al., 2011). The Farmana site, a settlement occupying a large area of 18 ha, lies within the basin of the river Chautang, a major tributary of the river Ghaggar, and is surrounded by a fertile land that was subject to extensive farming for the last half century. The rich arable land with its water resources was likely responsible for the establishment of such a flourishing Harappan site in this area. Moreover, the site of Farmana has the important Indus site of Rakhigarhi as a neighbor 40 km to its northwest. Located on the trade route between Rajasthan, a region famed for its rich mineral resources, and the important city of Harappa in Punjab, Farmana likely played a certain role in the flow of mineral and cultural resources, making notable contribution to the Harappan economy. It has been believed that the Khetri belt situated at the foothills of Aravalli Range of Rajasthan and northern Gujarat served as one of the major

copper sources for many Chalcolithic and Harappan cities, along with the areas of Baluchistan and Afghanistan, Oman and eastern Iran (Agrawala, 1984; Allchin and Allchin, 1982: 262; Kenoyer and Miller, 1999: 117; Law, 2008). It should be noted that Law (2008: 779), based on lead isotopic analyses, proposed the possibility of copper ores coming from northern Rajasthan to major Harappan cities. In addition, Weeks (2003: 172) made a reference to the work by Chakrabarti and Lahiri (1996: 192–196) to assert that copper mining commenced in India by the third millennium BC. Evidence was found that the occupation of the Farmana site began at the early Harappan phase and extended into the early historic period. The upper layers, however, had been completely removed by the recent farming activities and the major excavation was conducted for the strata belonging to the mature Harappan phase. The metal objects under investigation (Fig. 2) were all excavated from the settlement area of this period and date approximately between 2500 BC and 2000 BC on the basis of artifact typologies. The radiocarbon data included in the excavation report (Shinde et al., 2011: 833–834) place the calendar date between 2500 BC and 2200 BC, corresponding to the early part of the period inferred from typological investigation.

The site at Kuntasi (Fig. 1) is a settlement of approximately 3.3 ha located 72 km north of Rajkot, the headquarters of the Rajkot district in Gujarat. It lies on the right bank of the river Jhinhoda, 7 km away from the Gulf of Kutch. In antiquity, however, the site was likely situated much closer to the gulf and may have served as a seaport. The excavation of this site, conducted from 1987 to 1990 (Dhavalikar et al., 1996), produced evidence that it was constructed as a settlement starting from the mature Harappan phase, corresponding approximately to 2400 BC. The artifact assemblage excavated from it contained special items, apparently for trade, such as bichrome pottery and beads of carnelian, agate, chalcedony, jasper, steatite, faience, shells and lapis lazuli as well as items primarily for everyday life such as various ceramic ware and metal objects made of copper and copper alloys. The resources for most items were available in large quantities within 30 km from the site. It should be noted that Ratanpur, the major source of carnelian in Gujarat, is 250 km southeast from the site of Kuntasi while the famed copper source, the Khetri copper belt of Rajasthan, starts at Ambamata 150 km away from it. Certain mineral like lapis lazuli, however, may have come from Afghanistan (Allchin and Allchin, 1982: 169), which is also considered a key candidate for a source

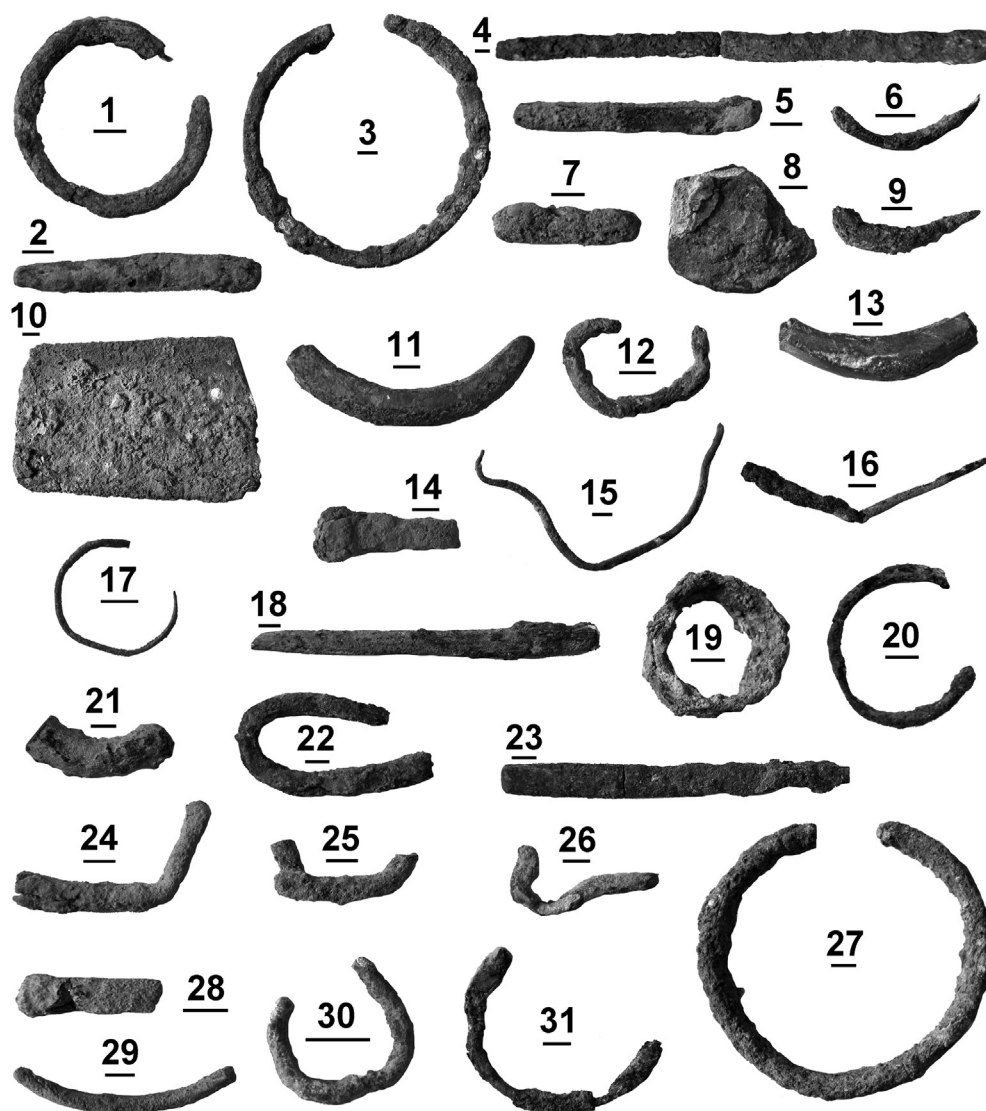


Fig. 2. General appearance of the bronze objects examined from the Harappan site at Farmana in Haryana, India. The objects, arranged according to chemical compositions, consist of 7 rings (objects #1, 6, 12, 17, 19, 20 and 30), 14 rod-type objects (#2, 4, 5, 7, 9, 14, 16, 18, 22–26 and 28), 7 bangles (#3, 11, 13, 21, 27, 29 and 31), 2 plate-type objects (#8 and 10) and 1 wire (#15). The bar near each object corresponds to 5 mm. The numbers labeling the objects are consistent with those in Table 1.

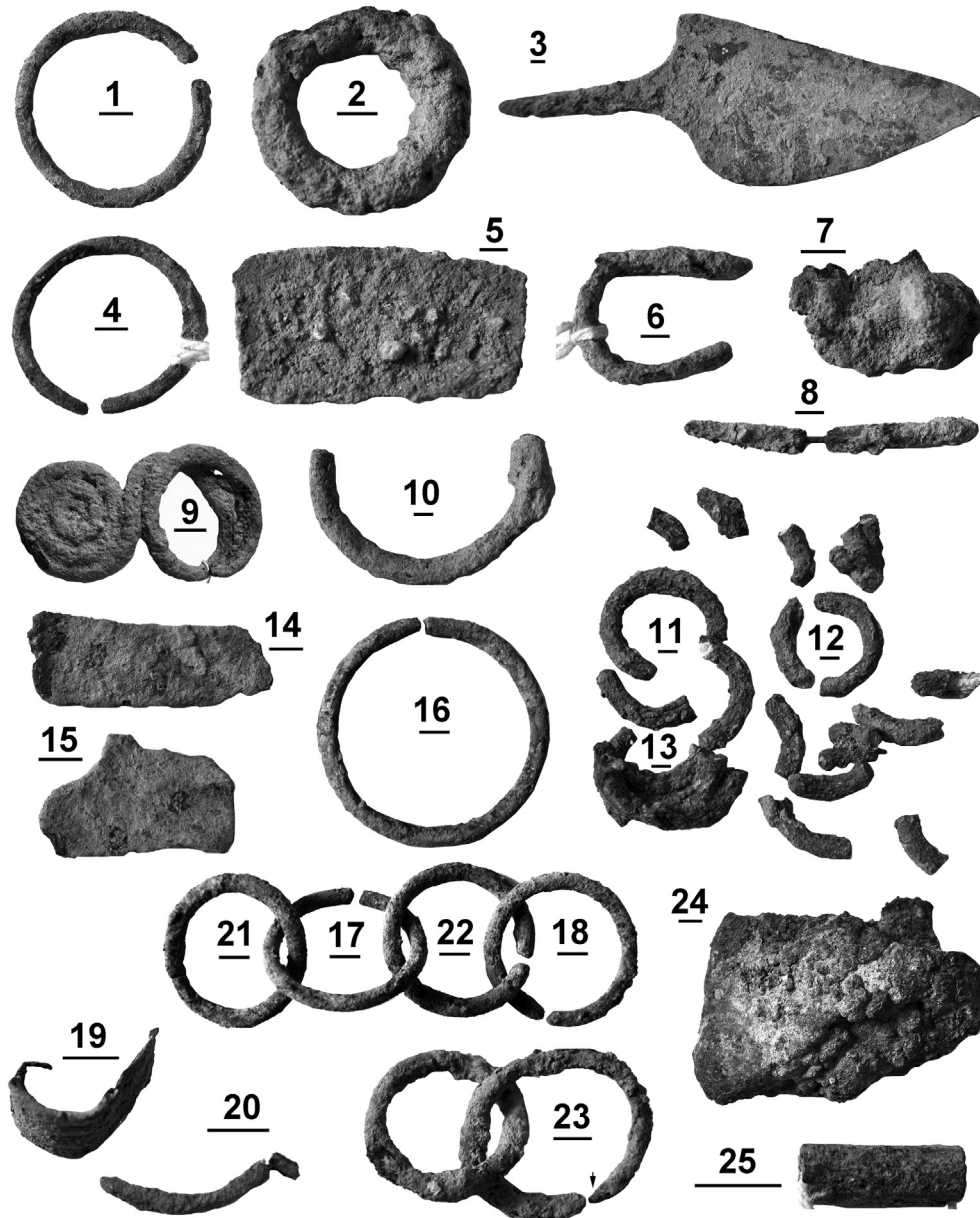


Fig. 3. General appearance of the bronze objects examined from the Harappan site at Kuntasi in Gujarat, India. The objects, arranged generally according to chemical compositions, consist of 11 rings (objects #1, 2, 4, 11, 12, 13, 17, 18, 21, 22 and 23), 1 spearhead (#3), 4 plate-type objects (#5, 14, 15 and 19), 3 rod-type objects (#6, 8 and 20), 1 casting splatter (#7), 1 double-spiral object (#9), 2 bangles (#10 and 16), 1 axe (#24) and 1 tube (#25). The bar near each object corresponds to 5 mm. The numbers labeling the objects are consistent with those in Table 2. Objects # 17, 18, 21 and 22 were recovered from one single spot in the form of a chain and cannot be arranged in correct sequence based on their composition.

of tin that was available in the Indus Valley (Kenoyer and Miller, 1999: 118; Weeks, 2003: 200). Based on the typological characteristics of artifacts recovered and its unique geographic location, the excavation report concluded that the site of Kuntasi was not a normal residential settlement but an industrial emporium on the west coast established by Harappan people. The major function of the site was likely to serve as a manufacturing and trading center connecting the resource-rich hinterland to other cities in the sub-continent as well as in West Asia. This premise is in agreement with the fact that the water resources in its vicinity are limited and mostly contaminated with salt, making the area unsuitable for agriculture. Although the site was apparently occupied from 2400 BC to 1700 BC, most objects recovered came from layers of the mature Harappan phase. The radiocarbon measurement on a carbon sample from an unknown carbon-bearing material from the

site showed that its calendar date falls approximately between 2200 BC and 2000 BC. In particular, the copper-base objects (Fig. 3) examined in this study mostly date between 2400 BC and 2000 BC and are roughly contemporaneous with those of Farmana (Fig. 2).

3. Comments on artifacts

The Farmana assemblage shown in Fig. 2 consists of 31 objects including 7 rings (#1, 6, 12, 17, 19, 20, 30), 7 bangles (#3, 11, 13, 21, 27, 29, 31), 14 rod-type objects (#2, 4, 5, 7, 9, 14, 16, 18, 22–26, 28), 2 plate-type objects (#8, 10) and a wire (#15). The name or purpose of each object determined on the basis of typological grounds is specified in Table 1, along with brief information about the context of recovery and chemical composition to be discussed in later sections. Note that the numbers labeling the artifacts are consistent

between Fig. 2 and Table 1. According to the information in Table 1, a more detailed classification is possible, but the simplified one given above is more effective at focusing on important aspects implied in their shape. If it is taken into account that rings and bangles are basically rods with varying curvatures, the first 3 groups can be merged and the classification can be further simplified into two groups consisting of either rod-type or plate-type objects. It is evident that the objects in Fig. 2, whether rods or plates, were apparently given a substantial degree of mechanical working during fabrication, suggesting that they are essentially of the same family and constitute products of the same technological tradition where forging plays a key role. In this tradition, rods, either curved or straight, can readily be forged into plates and plates can also be forged into rods without much difficulty. As such, all those in Fig. 2 may be considered either finished items with a specific purpose or product intermediaries for further processing. This hypothesis is supported by objects #6, 9, 11, 13, 21, 29 and 31, which are remnants of rings or bangles after pieces were cut off from them. Careful examination of the surface at either end of these objects revealed that they were not broken because of corrosion, but rather as the result of an intended action. Pieces thus prepared may have then been used as a medium to be forged into varying finished items.

A number of metal objects excavated from the Farmana site were previously examined and the metallographic results were briefly summarized in the excavation report (Shinde et al., 2011: 802–806) with no discussion on the implication of the analytical results. Some of them could have been offered for reexamination in this work.

The Kuntasi assemblage illustrated in Fig. 3 consists of 25 objects including 11 rings (#1, 2, 4, 11, 12, 13, 17, 18, 21, 22, 23), 2 bangles (#10, 16), 4 plate-type objects (#5, 14, 15, 19), 3 rod-type objects (#6, 8, 20), a spearhead (#3), an anonymous object (#7), a double-spiral object (#9), an axe (#24), and a tube (#25). The name or purpose inferred from typological investigation is given in Table 2, along with other information about the context of recovery and chemical composition for each artifact. The labeling system here is also consistent and each of the objects in Fig. 3 and Table 2 is labeled with the same number. The spearhead (#3) and the tube (#25) are not much different from the other plate-type objects and the double-spiral object (#9) was evidently forged out of a rod. As such, the Kuntasi assemblage is similar in composition to that of Farmana, and consists primarily of plate-type objects and rod-type objects of varying curvatures including rings, bangles and rods. The anonymous object (#7) and the object referred to as an axe (#24) are unique in that they retain a clear indication of the solidification reaction that occurred on their surface.

For the benefit of later discussion, additional comments should be made on the special relationship between some objects in the Farmana and Kuntasi assemblages and their position in Figs. 2 and 3. The artifacts are arranged in Figs. 2 and 3 according to their chemistry as is described in detail in the following section, and the distance between objects, i.e., the difference in the numbers labeling the objects, reflects the degree of variation in alloy composition. The two bangles (#3 and 27) situated with a large distance between them in Fig. 2 were excavated at the same spot. By contrast, objects #11, 12 and 13 positioned side by side in Fig. 3 were among the numerous rings recovered from the same location. The

Table 1

Summary information, including chemical composition, for the bronze objects examined from the Harappan site at Farmana in Haryana, India.

#	Artifact	Recovery date (dd-mm-yy)	No. given at excavation	Trench	Depth (cm)	Chemical composition based on weight %					Comments
						As	S	Fe	Zn	Pb	
1	Ring	28-03-08	1F308008	1F3 (ST.4B)	34–62	7.5	tr	tr	–	–	Worked and annealed
2	Rod	03-04-07	0307015	03 (test trench)	119–123	7.0	1.0	–	–	–	Worked and annealed
3	Bangle	02-04-08	1B308009	1B3	58	5.5	0.5	–	–	–	Worked and partially annealed
4	Rod in 2 pieces	02-04-08	1B308009	1B3	58	4.5	–	–	–	–	Worked and partially annealed; Particles of Cu-As-Ni and As ₂ O ₃
5	Rod	12-02-09	3T1709002	3T17	218–240	4.0	1.0	–	–	–	Worked and partially annealed
6	Ring	29-02-08	1D208009	1D2	37–40	4.0	0.5	–	–	–	Worked and partially annealed
7	Rod	19-02-09	3T1709007	3T17	268–270	3.5	1.5	–	–	–	Worked and partially annealed
8	Plate	19-03-08	1F108005	1F1	32–82	3.5	0.5	–	–	–	Worked and partially annealed
9	Rod	16-02-09	2D909006	2D9	84–90	3.5	0.5	–	–	–	Worked and partially annealed; 1.0% Sn
10	Plate axe	16-03-09	2XD4005	2XD4	143	3.0	0.5	–	–	–	Worked and partially annealed; 1.0% Ni
11	Bangle	14-04-08	Surface	Surface		3.0	0.5	0.5	–	–	Worked and partially annealed
12	Ring	08-02-09	3Z1709023	3Z17	200–207	3.0	0.5	–	–	–	Worked and annealed
13	Bangle	14-04-08	Surface	Surface		3.0	0.5	0.5	–	–	Worked and partially annealed
14	Rod	27-02-09	1C1109011	1C11	138–164	2.5	1.5	–	–	–	Worked and partially annealed
15	Wire	20-03-08	1F308007 (v1)	1F3	34–113	2.0	0.5	–	–	–	Worked and annealed
16	Rod	28-03-08	1F308008	1F3 (ST.4B)	34–62	1.0	1.0	–	–	–	Worked and annealed
17	Ring	16-03-09	2XE409031	2XE4	140–155	1.0	0.5	–	–	–	Worked and annealed
18	Rod	21-03-08	BA01k	1CB&1D3	24–34	0.5	1.0	–	–	–	Worked and annealed
19	Ring	06-02-09	3U1809013	3U18	252–262	–	0.5	–	–	–	Worked and annealed
20	Ring	09-03-08	3X08005	3X	149–164	–	1.5	–	–	–	Worked and partially annealed
21	Bangle	24-01-09	2XE50902	2XE5	133–142	–	0.5	–	–	–	Worked and annealed
22	U rod	22-02-09	2C909006	2C9	97–100	–	0.5	–	–	–	Worked and annealed
23	Rod	27-03-08	1C408003	1C4	50–56	–	0.5	–	–	–	Worked and annealed
24	Rod	13-03-09	1D809015	1D8	60–74	–	0.5	–	–	–	Worked and annealed
25	Rod	16-02-10	2C510005	2C5	46	–	–	–	–	–	Worked and annealed; Cu-Cu ₂ O eutectic
26	Fish hook	03-02-09	2XD509006	2XD5	134–140	–	–	–	–	–	Worked and annealed; Cu-Cu ₂ O eutectic
27	Bangle	02-04-08	1B308009	1B3	58	–	–	–	–	–	Worked and annealed; Cu-Cu ₂ O eutectic
28	Flat rod	14-02-09	1A909006	1A9	40–51	1.0	–	–	23.0	tr	Worked and annealed
29	Bangle	29-01-09	1B1009003	1B10	55–61	–	0.5	0.5	22.0	tr	Worked and annealed
30	Ring	06-02-09	1D1109001	1D11	31–71	–	0.5	–	20.0	6.0	Cast and annealed
31	Bangle	20-01-09	1F809007	1F8	55–60	–	0.5	–	16.5	tr	Worked and annealed

– None detected; tr trace amount.

Table 2

Summary information, including chemical composition, for the bronze objects examined from the Harappan site at Kuntasi in Gujarat, India.

#	Artifact	Recovery date (dd-mm-yy)	No. given at excavation	Trench	Depth (cm)	Layer	Chemical composition based on weight %					Comments
							As	Sn	S	Fe	Ni	
1	Ring	27-01-90	5589	J-9	20	6	7.0	—	0.5	0.5	—	Worked and partially annealed
2	Rings	27-12-89	4777	I-7	40	8	5.5	—	1.0	0.5	1.0	Worked and partially annealed
3	Spearhead blade	28-12-88	2107	G1	80	6	4.5	—	0.5	0.5	—	Severely cold worked and partially annealed
	Spearhead tail						6.0	—	tr	0.5	—	Cold worked and partially annealed
4	Ring	29-01-90	5564	V10SE	70	8	5.5	—	0.5	0.5	0.5	Worked and annealed
5	Blade	30-01-90	5621	I-9	25	6	3.0	—	1.0	0.5	—	Severely worked and partially annealed
6	U-shaped rod	08-02-90	5734	C14	Surface		2.0	—	tr	—	—	Worked and annealed
7	Casting splatter	07-02-90	5723	Ja	65	8	1.5	—	0.5	tr	0.5	Cast
8	Awl	30-01-90	5612	I-9	30	7	1.0	—	tr	0.5	—	Worked and annealed
9	Double spiral	05-01-90	4960	C12	40	6	1.0	—	0.5	—	1.0	Worked and annealed
10	Bangle	10-01-90	5101	A12	25	6	0.5	—	0.5	—	—	Worked and annealed
11	Ring	30-12-89	4819	C15	NA	7	0.5	7.5	0.5	—	—	Worked and fully annealed
12	Ring	30-12-89	4819	C15	NA	7	0.5	7.0	0.5	—	—	Worked and fully annealed
13	Ring	30-12-89	4819	C15	NA	7	0.5	6.5	0.5	—	—	Worked and fully annealed
14	Blade	12-01-90	5161	F-9	55	6	2.5	5.5	0.5	0.5	—	Severely worked and annealed
15	Sheet fragment	09-01-90	NA	E 12	45	7	2.0	5.5	0.5	0.5	—	Severely worked and fully annealed
16	Bangle	30-01-90	5623	J-9	10	6	1.0	5.0	1.0	—	—	Worked and fully annealed 4.0% Pb
17	Ring	30-01-90	5623	J-9	10	6	—	4.0	0.5	—	—	Worked and fully annealed
18	Ring	30-01-90	5623	J-9	10	6	—	4.0	0.5	—	—	Worked and fully annealed
19	Curved plate	30-01-90	5617	J-9	10	6	1.5	3.0	0.5	0.5	—	Worked and fully annealed
20	Fishhook	20-01-90	5486	G11	15	7	2.0	2.5	0.5	—	—	Worked and fully annealed
21	Ring	30-01-90	5623	J-9	10	6	3.5	2.0	0.5	—	—	Worked and annealed
22	Ring	30-01-90	5623	J-9	10	6	3.5	2.0	0.5	—	—	Worked and annealed
23	Ring	29-01-88	526	D1	45	2	—	0.5	tr	—	0.5	Forged
24	Axe	29-01-90	5568	L-12	30	7	—	—	1.5	—	—	Cast and fully annealed; Intermediary
25	Tube (bead)	04-02-89	4278	L-3	50	13	2.0	0.5	1.0	1.5	—	Cast and fully annealed; 6.5% Zn and 14.0% Pb
26	Anonymous	07-02-88	903	OE3	230	16	Unidentified carbon-bearing material					AMS dated

— None detected; tr trace amount; NA information not available.

bangle (#16) and the 4 rings (#17, 18, 21 and 22) in Fig. 3, all found in the same spot, show a notable difference in chemical composition but the rings, forming a chain, cannot be arranged individually according to the artifact number.

4. Analytical procedures and results

During his visit to Deccan College in Pune, India, one of the authors (JSP) took one or two small specimens from each of the objects shown in Figs. 2 and 3. The specimens were then prepared in his archaeometallurgy lab at Hongik University in Korea, following a standard metallographic procedure consisting of mounting, polishing and etching with a solution of 100 ml methyl alcohol, 30 ml hydrochloric acid and 10 g ferric chloride. Their microstructures were examined using an optical microscope and a scanning electron microscope (SEM). The alloy composition was measured using the energy dispersive x-ray spectrometer (EDS) included with the SEM instrument and reported in Tables 1 and 2 in weight fraction to within 0.5%, even though the EDS instrumentation is capable of providing accuracy readings to within a few tenths of a percent. The average composition of each specimen was inferred from the EDS spectrum taken in a raster mode from an area of approximately 0.65×0.45 mm, except in cases where restrictions on the specimen size necessitated a smaller area.

4.1. Alloy composition

The chemical composition of the metal objects from the two Harappan sites at Farmana and Kuntasi is summarized in Tables 1 and 2, respectively. Of the alloying elements listed in the tables, only arsenic, tin, zinc and lead had notable effects on alloy properties while the presence of other minor elements such as sulfur,

iron and nickel was likely fortuitous and not predictable. The objects in Tables 1 and 2 may then be classified according to the primary alloying element into arsenical copper, tin bronze, brass and unalloyed copper groups. A more detailed classification is necessary if the three objects (#16 and 25 in Table 1 and #30 in Table 2), containing a substantial amount of lead, are taken into account. We will use the simplified one, however, to focus on the more important aspects to be addressed.

The objects from the Farmana site are arranged in Table 1, and also in Fig. 2, based on their alloy compositions. This arrangement makes it clear that they consist of arsenical copper objects (#1–18), unalloyed copper objects (#19–27) and brass objects (#28–31). Careful examination of Table 1 reveals several facts of significance. First of all, arsenic served as the single alloying element in approximately 60% of the objects while 30% of them were made of unalloyed copper. The arsenic concentration is seen to vary significantly from 0.5 to 7.5%. By contrast, the remaining 10% of the objects in Table 1 are those made of brass alloys with their zinc concentration ranging from 16.5% to 23.0%, averaging 20.4%. Another fact of significance is the nearly perfect absence of tin in any of the objects, with only one exception found in object #9 whose tin level is 1.0%. Objects #10 and 31 are also exceptional for their respective 1.0% Ni and 6.0% Pb contents. It is important to note that lead was included in all the brass objects while no lead was detected in any of the arsenical copper and the unalloyed copper objects.

The objects from the site at Kuntasi are also arranged in Table 2 and Fig. 3 according to their chemical compositions. In the Kuntasi assemblage, arsenic and tin were widely used as the major alloying elements and most objects were made of alloys containing either arsenic or tin or both. The only exception to this is found in object #24, an axe made of copper containing no other alloying element

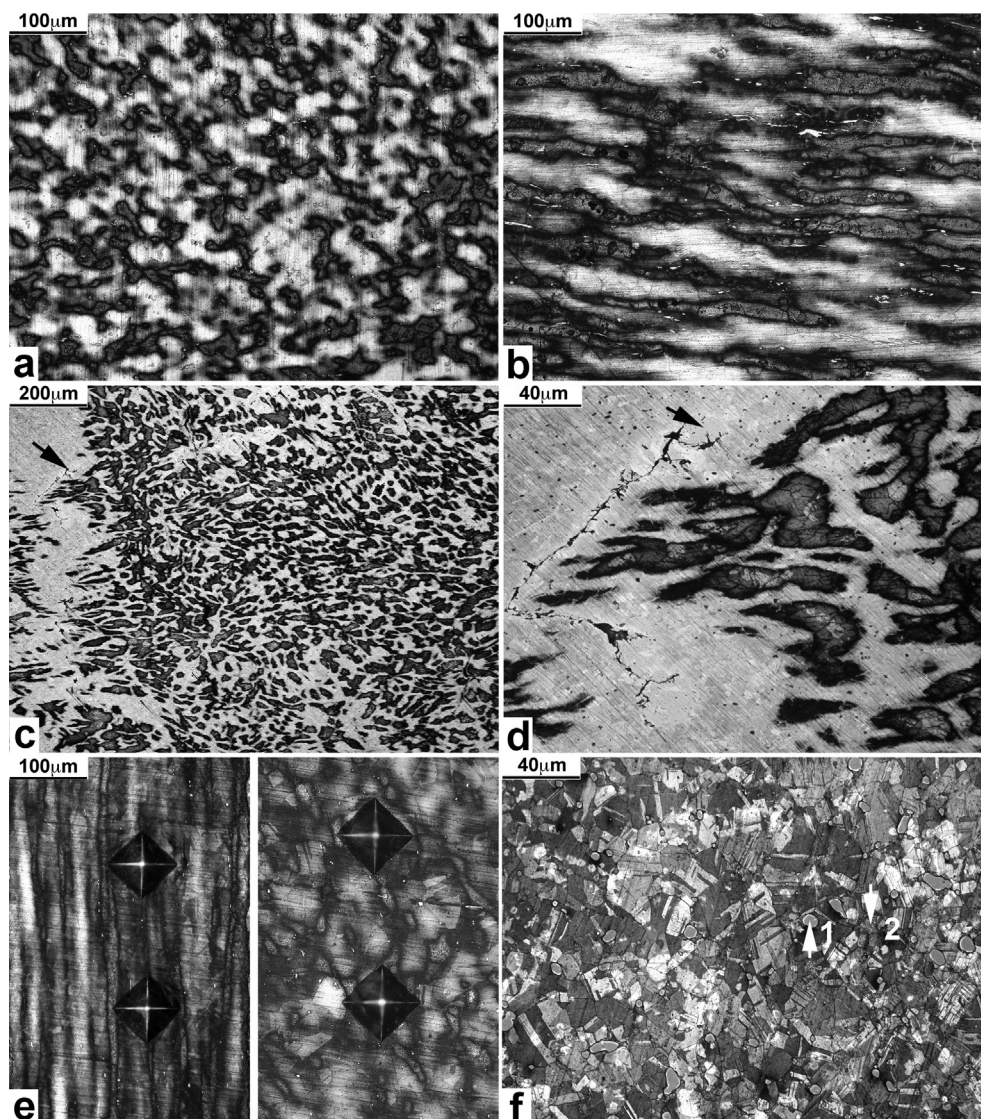


Fig. 4. Optical micrographs showing structures of some specimens containing arsenic as a major alloying element. (a), (b) Specimen taken from Farmana object #3 (bangle) of Fig. 2; (c), (d) specimen taken from object 6 (rod) of Fig. 2; (e), (f) specimens taken from Kuntasi object #3 (spearhead) and #16 (bangle) of Fig. 3, respectively.

than sulfur. The composition data in Table 2 show considerable variations in arsenic levels ranging from 0.5 to 7.0% and also in tin levels from 0.5 to 7.5%. Notable patterns, however, are recognized when the variations in tin and arsenic levels are viewed together. First of all, no tin was added in objects with 5.5% arsenic or more (see #1–4). Arsenic, however, was detected in almost every object of Table 2, even in those of relatively high tin contents. It is important to note that of the objects with both tin and arsenic, the arsenic level is generally higher in the low tin objects whose tin level is 3.0% or below (see #19–22) while those with high tin levels of 6.5% or above contain little arsenic (see #11, 12 and 13).

4.2. Microstructures

Fig. 4a–f presents optical micrographs showing the structures typically observed in the majority of specimens examined, i.e., those containing arsenic with or without the addition of tin. Specimens with arsenic react sensitively with the etching solution and, when etched, produce a strong contrast on the polished

surface, depending on arsenic content. The contrast clearly visible in all the given micrographs therefore depicts the non-uniform arsenic distribution. Fig. 4a, b illustrates the microstructures observed in two different sections of the specimen from object #3 of Fig. 2, a bangle. The structures in both micrographs consist of the single alpha phase of the Cu–As alloy system. Here the conspicuous contrast demonstrates the local variation in arsenic content determined by the strong tendency of arsenic to segregate in solidification. The dark areas correspond to the primary phase precipitated earlier in the form of dendrites while the white background represents the phase precipitated later filling the region between the dendrites. In view of the limited solubility of arsenic in solid copper, arsenic must have been enriched in the white area that was precipitated near the end of the solidification reaction. The morphological characteristics determined during solidification, however, are almost lost in both Fig. 4a, b, indicating that the specimen was treated with a substantial degree of mechanical working subsequent to casting. It is seen that the dark areas in Fig. 4b was much elongated, evidently along the forging

planes arranged parallel to the circumferential direction of the bangle. By contrast, the degree of deformation along the radial direction shown in Fig. 4a is almost negligible.

The contrast in Fig. 4c, illustrating the structure of object #5, a rod, in Fig. 2 is mostly similar to that of Fig. 4a except at the left edge where the fraction of white area is greatly increased. The increased fraction of the arsenic-enriched white area reflects the increase in the average arsenic level. As such, the arsenic concentration inferred from Fig. 4c is non-uniform and shows a significant variation, particularly near the left edge. Apparently, the mixing of the molten alloys prepared for the casting of this particular object was not complete. This incomplete mixing produced another effect as is shown in Fig. 4d, magnifying the vicinity of the arrow near the upper left corner of Fig. 4c. Fig. 4d shows a second phase included within the white area as at the locality marked by the arrow. This is the gamma phase of the Cu-As alloy system whose arsenic level is approximately 30%. The cracks shown propagated along this gamma band in Fig. 4d indicate that this phase is prone to brittle fracture. The EDS analysis done in a raster mode on Fig. 4c away from the arsenic-enriched left edge showed that this specimen contains 4.0% As and 1.0% S in addition to copper. The presence of the gamma phase in this specimen, however, indicates that the arsenic level at the specific region was much higher than this average value.

Fig. 4e consists of two micrographs showing the microstructure of object #3 in Fig. 3, a spearhead from the Kuntasi assemblage. The micrograph in the left hand side shows the structure at the head while that in the right hand side presents the structure at the tail. The left figure, consisting of the alternating dark and bright layers, demonstrates the extensive deformation given for the shaping of the blade. The degree of deformation is much less pronounced in the right figure, which illustrates the structure in the cross section of the tail. EDS analyses revealed that the arsenic content is lower at the blade (4.5%) than at the tail (6.0%). The dark rhombuses in Fig. 4e, the result of Vickers hardness (Hv) measurements, correspond approximately to Hv = 120 and 95 in the left and right figure, respectively. The higher hardness noted at the blade, despite its arsenic level significantly lower than at the tail, is an unmistakable evidence of the extensive deformation applied to the blade.

Fig. 4f, illustrating the structure of object #16, a bangle, in Fig. 3 consists of the twinned alpha background over which particles of copper sulfide, i.e., matte, as at the spot marked by arrow 1, are scattered. Although not clearly visible in this low magnified micrograph, particles of almost pure lead are also widely spread as at arrow 2. This structure is typical of those observed in sulfur-contaminated copper alloys with added lead when they are forged and then annealed at elevated temperatures. The alloy composition as inferred from the EDS analysis on the specimen under consideration was 89% Cu-1.0% As-5.0% Sn-4.0% Pb-1.0% S. This specimen is, therefore, distinguished from those presented above in two respects. It was given a much fuller annealing treatment following the mechanical working. In addition, it was made of alloys containing a substantial amount of tin and lead. The lead level of 4.0% may have resulted from intentional addition (Craddock, 1979). The evidence of mechanical working applied to this specimen, however, is unexpected since bronze alloys with such a lead content can hardly be worked at temperatures above the melting point of lead. It seems likely therefore that the object was cold worked and then heated for annealing. The contrast in brightness, though not strong, superimposed on the underlying microstructure in Fig. 4f is indicative of the small amount of arsenic present in the alloy.

Fig. 5a–d presents spectra obtained from the EDS analyses on some of the specimens whose microstructures were presented above. Fig. 5a, a spectrum taken in a raster mode from the entire

area of Fig. 4a, shows this specimen to contain arsenic and sulfur in addition to copper. The average arsenic and sulfur levels inferred from Fig. 5a were approximately 5.5% and 0.5%, respectively. Fig. 5b, a spectrum taken in a point mode from the gamma phase marked by the arrow in Fig. 4d, shows the arsenic content to be approximately 30.0% in keeping with the reading from the Cu-As phase diagram. Fig. 5c, an EDS spectrum from one of the scattered particles at arrow 1 of Fig. 4f, shows it to be copper sulfide contaminated with a significant amount of iron. Fig. 5d, a spectrum from the particle at arrow 2 in Fig. 4f, reveals it to consist of almost pure lead.

Fig. 6a–c shows optical micrographs bearing special features that are not observed in the micrographs presented above. Fig. 6a, showing the microstructure of object #21 in Fig. 2, a bangle, consists of the primary alpha phase in dendrites with the inter-dendritic regions filled with the dark Cu-Cu₂O eutectic structure. Morphological characteristics of the original casting are mostly retained in Fig. 6a. Some of the alpha areas are lightly twinned, however, suggesting that the specimen was slightly forged after casting. This premise is in agreement with the expectation based on the curved shape of the object, which provides a ground for classifying it as a bangle. Fig. 6b, showing the structure of object #7 of Fig. 3, an irregular piece of unknown purpose, also consists primarily of the alpha phase in the form of dendrites with a number of sulfide particles placed mostly in the dark inter-dendritic regions. No evidence of mechanical working observed in the structure indicates that the object maintains the shape determined by casting. It seems reasonable therefore to name it a casting splatter. The structure in Fig. 6c, from object #24 in Fig. 3, an axe, consists of large alpha grains forming the background where numerous matte particles are scattered. The fully developed grain structure demonstrates the complete annealing treatment given subsequent to casting. There is no evidence observed in Fig. 6c for mechanical treatments applied. It is evident therefore that the object was not meant for use as a real axe, but rather as a product intermediary cast for trade or further processing.

Surprisingly, some objects from both the Farmana and Kuntasi assemblages were made of brass with a considerable amount of zinc, as can be seen in the analytical results summarized in Fig. 7a–d. Fig. 7a–c, optical micrographs showing the structure of objects #28 (flat rod), 29 (bangle) and 30 (ring) of Fig. 2, respectively, have the alpha phase of the Cu-Zn system in their background where numerous dark particles of almost pure lead are scattered. The dark rhombuses in Fig. 7a correspond to the Vickers hardness of around 100, which is comparable to the hardness measured in the right hand side of Fig. 4e. The dark networks and the large-scale horizontal crack seen in Fig. 7b resulted from substantial corrosion that occurred along the grain boundaries during the long period in the soil. It is important to note that the original cast structure was lost in Fig. 7a, b due evidently to the subsequent mechanical treatment while no evidence for such treatment is found in Fig. 7c where some features determined during casting are still retained. Fig. 7d, an optical micrograph showing the structure of object #25 of Fig. 3, a small tube, consists of large alpha grains and, at their boundaries, dark areas of almost pure lead frequently dotted with matte particles. The bright angular particles marked by the arrows represent iron phosphide.

4.3. Accelerator mass spectrometric (AMS) dating

An irregularly shaped fragment of an unidentified carbon-bearing material recovered from the Kuntasi site (see #26 in Table 2) was sent for AMS measurements to the University of Arizona's NSF-Arizona AMS Facility for ¹⁴C analysis. The result is summarized in Table 3 where the calendar age was calculated using Calib Rev 6.1.0 (Reimer et al., 2009) in conjunction with the

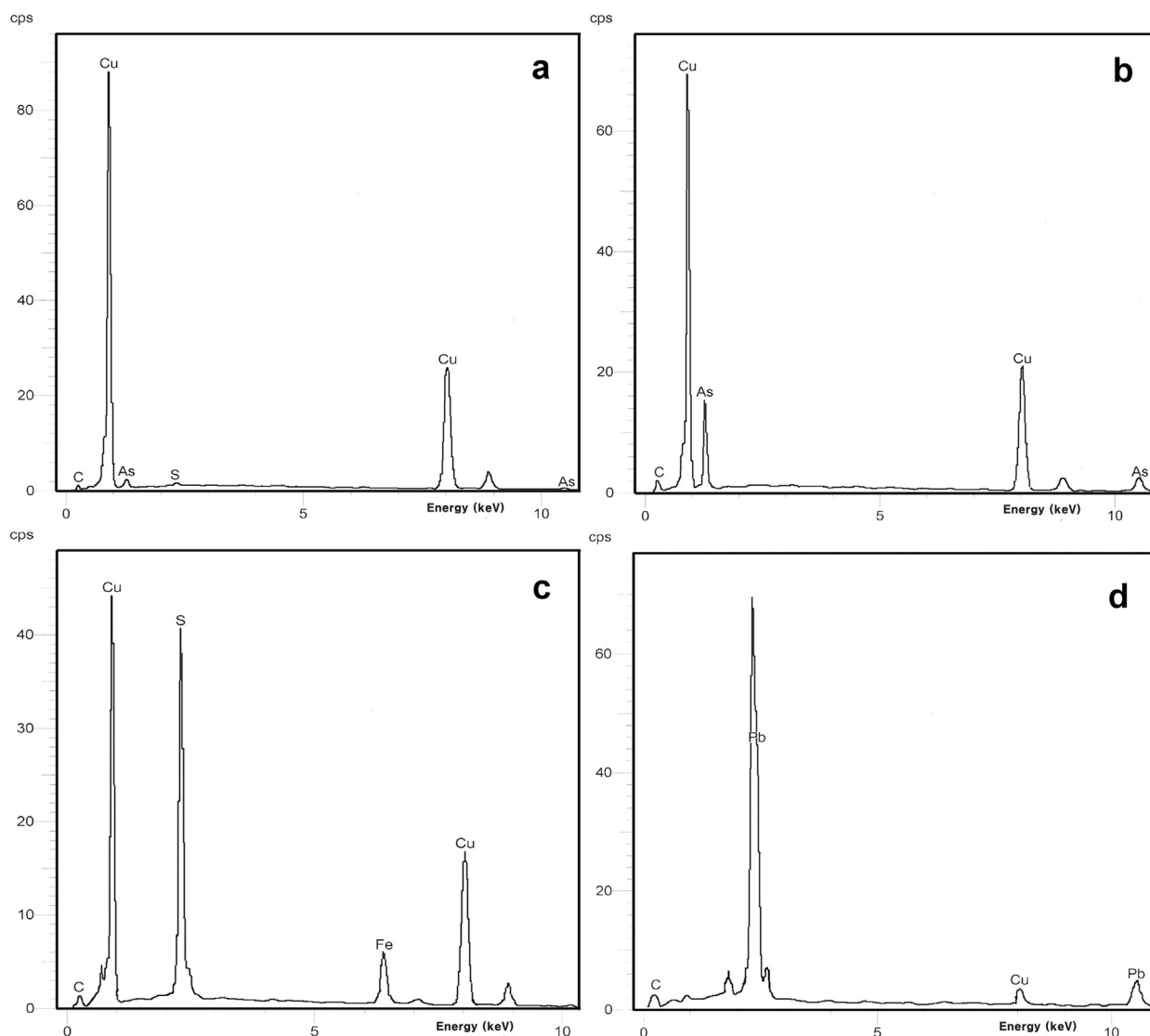


Fig. 5. EDS spectra. (a) Spectrum from the entire area shown in Fig. 4a; (b) spectrum from the spot marked by the arrow in (c) and (d); (c), (d) spectra from arrow 1 and 2 in Fig. 4f, respectively.

extended ^{14}C database (Stuiver and Reimer, 1993). The 1σ ^{14}C age of the object measured is 3719 ± 41 years before present (yr BP) as of 1950. This result, when calibrated within a 2σ probability range, placed the calendar date approximately between 2200 BC and 2000 BC, in fair agreement with the estimation based on typological grounds.

5. Discussion

5.1. Alloy composition and microstructure

The composition data in Tables 1 and 2 show the presence of arsenic, tin, lead, zinc, sulfur, iron and nickel as alloying elements in the artifacts examined. The latter three may have originated from the inadvertent use in smelting of special copper ores, with their concentration determined in an unpredictable manner depending on the conditions given during smelting and various post-smelting processes. The discussion here therefore will ignore their presence and focus on the major alloying elements added in a more or less informed way.

It is seen in Tables 1 and 2 that arsenic played a particularly important role in both the Farmana and Kuntasi metal assemblages. Arsenic was detected virtually in every object, even in those, which contain a substantial amount of tin and therefore can get no further effect from its addition in such a small amount (see #11–13). This can happen if copper contaminated with arsenic is used as a base material for tin alloying. One may then presume that arsenic-contaminated copper was regularly produced for use as an ordinary copper material, which frequently served as a raw metal for tin alloying. As opposed to tin and lead that were generally added in elemental form, however, arsenic was generally introduced in copper through the use, whether intentionally or inadvertently, of arsenic-bearing minerals in the smelting of copper (Lechtman and Klein, 1999). Consequently, addition of arsenic could occur unintentionally in the smelting of arsenic-contaminated copper ores, and control over the exact amount of arsenic included in an object was nearly impossible, as can be seen in the large variation of arsenic levels in Tables 1 and 2.

The variability in arsenic contents, therefore, makes it difficult to distinguish between objects resulting from intended and unintended arsenic alloying. An important solution to this difficulty is

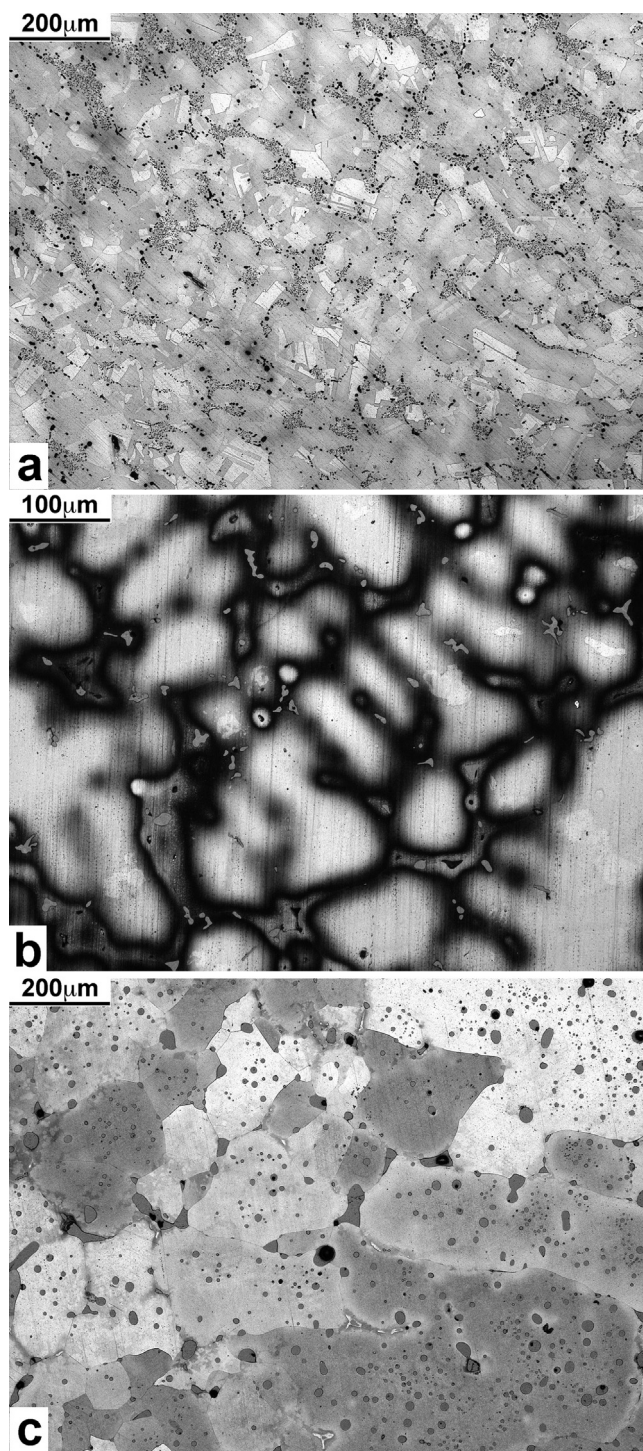


Fig. 6. Optical micrographs. (a) Microstructure of the specimen taken from Farmana object #21 (bangle) of Fig. 2; (b), (c) microstructure of the specimens taken from Kuntasi object #8 and 24 of Fig. 3, respectively.

found in the chemistry of objects #11–18 of Table 2 whose tin content is relatively high. Their arsenic concentration rarely exceeds 2.0%, suggesting that the arsenic level below approximately 2% may be understood as the result of an inadvertent arsenic contamination, but not necessarily as intended to make arsenical copper alloys. By contrast, the presence of arsenic by 1.5–3.5% in objects #19–22 of Table 2 likely resulted from an informed selection to compensate for their somewhat limited tin fraction

(2.0–3.0%). Particular evidence for this premise is reflected in the different alloy composition between objects #17–18 and #21–22, all recovered from the same spot in the form of a chain as shown in Fig. 3. The former contain 4.0% Sn with no arsenic while the latter contain 2.0% Sn in addition to 3.5% As. The chemistry unusually consistent in each group strongly suggests that the two-fold difference in tin levels between the two groups resulted from an intended and informed selection of arsenical copper as a raw material for tin alloying. Incidentally, no tin was added in objects #1–4 of Table 2 whose arsenic content is above 5.0%, higher than in any other objects. It seems evident therefore that the Kuntasi metalworkers were aware of the chemistry of base copper available for tin alloying and carefully determined the tin level according to its arsenic concentration.

Objects #28–31 in Table 1 are distinguished from the others in the Farmana metal assemblage in their high zinc content, which endows them with significance as one of the earliest examples of the extant brass products (Thornton, 2007). Their high zinc level mostly 20.0% and above is within the range that can readily be achieved with the historical cementation process (Dutrizac and O'Reilly, 1984; Park and Voyakin, 2009). According to Dr. Craddock (*pers. comm.*) at the British Museum, however, brass objects at such an early period may have been produced accidentally rather than intentionally through a process that was already well established. Thornton (2007) proposed smelting of the mixture of copper ores with zinc oxides as a more likely method utilized for the production of prehistoric zinc alloys. A sharp contrast between these brass objects and others is also confirmed in the presence of lead. Lead was consistently observed in all the brass objects but no lead was detected even in a trace amount in any of the others. This difference in alloy composition suggests the presence of multiple sources from which the Harappan community at Farmana acquired copper and copper alloys. A similar conclusion may also be drawn from the only brass object in the Kuntasi collection of Table 2, except that it was apparently made of re-melted metal scraps of varying alloy composition, which were likely recycled.

If we exclude the 5 brasses and take somewhat arbitrarily, based on the previous discussion, the arsenic level of 2.0% as a reference for classification, 15 of the 27 Farmana objects and 11 of the 24 Kuntasi objects were made of alloys with intentionally added arsenic. It should be noted, however, that in the Farmana assemblage arsenic was the single major alloying element while in that of Kuntasi arsenic and tin share the role independently or in combination.

The addition of arsenic and tin in bronze helps to facilitate the process of casting by lowering melting temperatures and improving flow characteristics. In addition, their presence up to approximately their solubility limit in solid copper progressively improves mechanical properties of the alloys. Despite all these desirable effects, the data in Tables 1 and 2 show the average concentration of arsenic and tin to be significantly below the solubility limit of either element. This fact suggests that access to either element, especially tin, was seriously limited. Even with this restriction in material resources, however, the Harappan communities at Farmana and Kuntasi seem to have successfully met their need for metal products, primarily by developing a unique method of fabrication involving substantial forging, as can be seen in the last column of Tables 1 and 2. The use of mechanical working during fabrication is effective at removing defects arising frequently from the casting of unalloyed or insufficiently alloyed copper (see Fig. 6a). Besides, strengthening of materials achieved from it can make up for disadvantages associated with lack of alloying elements.

In such a particular bronze tradition based on forging, however, the use of lead has to be minimized as it causes considerable

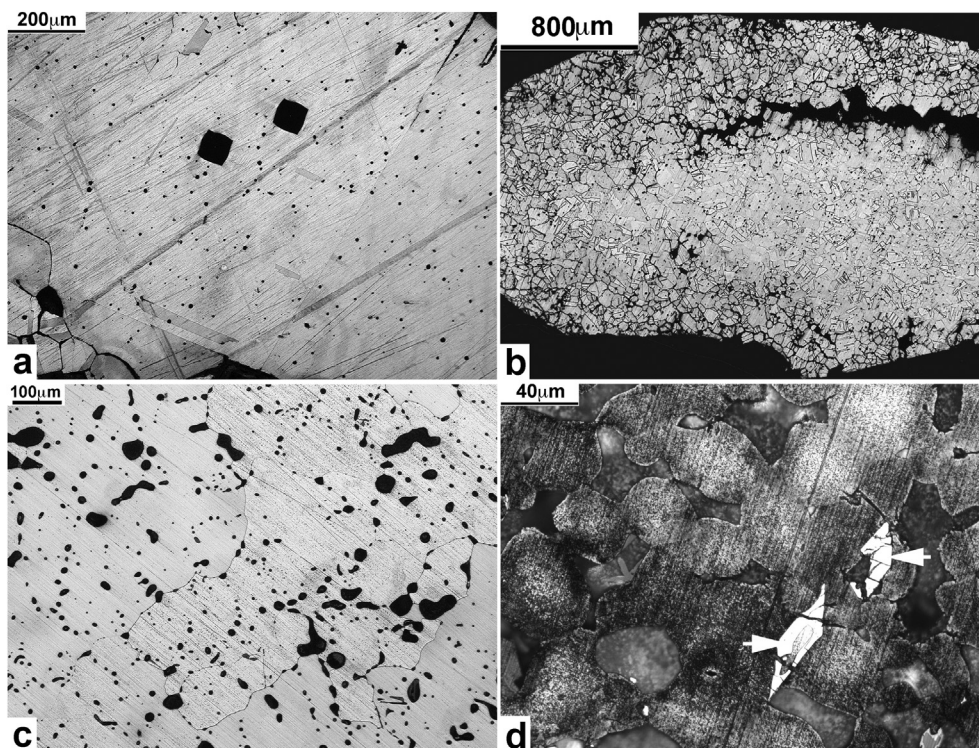


Fig. 7. Optical micrograph of the specimens taken from brass objects. (a)–(d) Optical micrographs showing the structure of Farmana object #28 (flat rod), 29 (bangle) and 30 (ring) of Fig. 2 and Kuntasi object #25 of Fig. 3, respectively.

reduction in impact resistance and allows no mechanical working to be given in any appreciable extent. Due evidently to this harmful effect, only 3 of the objects examined are found to contain lead in a notable amount, #30 in Table 1 and #16 and 25 in Table 2. Their lead concentration of 4.0% or above is too high to be considered accidental (Craddock, 1979). Moreover, two of them with higher lead contents (#30 in Table 1 and #25 in Table 2) were fabricated exclusively by casting (see Fig. 7c, d), indicating that their lead content was taken into account in the selection of such an unusual technique rarely employed in the local bronze industry at the time. In fact, one of them (#30 in Table 1) is the only object of the Farmana assemblage that was fabricated without mechanical working applied after casting. This suggests that the metalworkers distinguished between alloys with and without added lead and applied no mechanical treatment to those with added lead.

5.2. Product intermediaries in Indus copper-base industry

Despite the conspicuous difference in the use of tin between the Harappan metal assemblages from Farmana and Kuntasi, no noticeable difference is apparent in their artifact type as illustrated in Figs. 2 and 3. Apart from the minor difference in their detailed appearance, the objects may be classified into two types, rods (curved or straight) and plates. Even this classification seems meaningless if it is taken into account that such metallic rods and plates can change shape easily by hammering. In a certain sense, therefore, they may all be regarded as product intermediaries for further processing. One thing that matters in this hypothesis is the proper chemistry required to provide the end product with desired functional properties. When the composition data in Tables 1 and 2 are reviewed in association with the artifact positions in Figs. 2 and 3, reflecting alloy composition, correlation between artifact type and chemistry is visible only in plate-type objects, but not in rod-type objects. For instance, object #3 (a spearhead) and #5, 14 and

15 (blades) in Fig. 3 were made of high arsenic or high tin–arsenic alloys. Furthermore, their microstructure consistently shows evidence of cold working given to such a great extent that is never observed in the other objects examined. Similarly, every plate object (#8 and 10) in Fig. 2 contains a substantial amount of arsenic. One exception is found in object #24 in Fig. 3, which was named an axe but turned out to be a product intermediary. This object is reminiscent of the axe discussed by Thornton and Lamberg-Karlovsky (2004) from Tepe Yahya in Southeastern Iran. They noted that it was likely used as an ingot from which strips or rods could be cut for further processing.

Evidently, the metalworkers at the Harappan Farmana and Kuntasi towns were aware of material properties as determined by alloy composition and various thermo-mechanical treatments. This fact is reflected in the fact that high arsenic or tin alloys were used for most plate-type objects that were fabricated by forging while objects of high lead contents were made exclusively by casting. The use of materials away from optimum alloy concentrations in the two Indus communities therefore does not necessarily mean ignorance of the optimal arsenic or tin level for best mechanical properties. Instead, it should be understood as reflecting relative inability to get access to such materials, likely for economic and technological reasons. On the other hand, the artifact shape illustrated in Figs. 2 and 3 demonstrates that copper and bronze products available at the time were supplied most frequently in the form of rods. These products, if pre-alloyed, may have readily served as an intermediary to be forged into various functional items requiring high strength. If not, however, they could not be used for such special purposes until their tin or arsenic level was raised in a complicated and costly process involving melting the products. The seemingly unpredictable variation in their chemistry should therefore be understood as intended by the metal producers to meet varying needs on the consumer side. This interpretation then removes ambiguities surrounding the unexpected use of expensive

Table 3

Results of the AMS radiocarbon measurement on a carbon sample from an unidentified carbon-bearing material excavated at Kuntasi (see object#26 in Table 2). The measurement was made in the University of Arizona's NSF-Arizona AMS Facility for ^{14}C analysis.

Lab code	$\delta^{13}\text{C}$ (‰)	$1\sigma^{14}\text{C}$ age (yr BP)	95.4% (2 σ) cal age ranges (AD)
AA99895	−12.0	3719 ± 41	2276–2253 BC (2.8%) 2227–2223 BC (0.3%) 2209–2014 BC (94.5%) 1998–1979 BC (2.3%)

yr BP: year before present (AD 1950).

alloys with added tin or arsenic in making bangles and rings. Alloying would not have been necessary if they were to be used only for ornamental purposes. If such items were intended for use as intermediaries, however, it must have been required for their chemistry to be adjusted depending on their anticipated purpose in service. In this case, it would not be easy to determine the relationship between artifact types and alloy compositions (Hoffman and Miller, 2009: 248).

5.3. Comparison with other Indus sites

The composition data in Tables 1 and 2 are not much different from the data compiled by Kenoyer and Miller (1999). Both data sets contain unalloyed copper as well as copper alloys with their tin and arsenic contents determined mostly in the range guaranteeing substantial mechanical working to be readily applied. Evidence for the intended use of lead is observed, but objects with such evidence are rather exceptional in both the data sets. The presence of brass objects and the significantly higher portion of alloyed objects than that of the unalloyed, especially in the Kuntasi assemblage, are unique to our data as compared with those by Kenoyer and Miller. Another important difference is that their data show no evidence for the presence of arsenic, even in a trace amount, in any of the objects from the Harappan sites at Lothal and Rangpur, located also in Gujarat not far away from Kuntasi. In our Kuntasi assemblage, however, arsenic was detected in most objects, even in those with added tin, suggesting that arsenical copper alloys were amply available even for use as a base material in tin alloying. This discrepancy should be seriously addressed in future studies, especially in the discussion of arsenic as a plausible indicator of ore sources (Kenoyer and Miller, 1999: 117–118).

In spite of the differences in alloy chemistry, the data sets presented above point consistently to the fact that the alloys were mostly designed for use in a bronze tradition where forging was a major fabrication method. The dependence on mechanical working for fabrication as dictated by alloy compositions therefore may not have been unique to the Harappan towns at Farmana and Kuntasi, but a common feature characterizing the general bronze tradition of the Indus communities. The major advantage of this technological tradition lies in the fact that the need for most metal products can readily be met with minimal investments for engineering facilities and technical skills. Hammers and anvils and simple heating devices are all that is required. In addition, no elaborate casting would be necessary and the requirement for alloying elements would be much lessened. The data in Table 1, showing evidence of neither smelting nor melting done at the site, indicate that this type of bronze industry was in fact established in the Harappan farming community at Farmana. The technological environment as inferred from the data in Table 2 for Kuntasi is not much different. The use of tin as an alloying element and the evidence for handling molten alloys at the site, features unique to Kuntasi, should then be

understood as a regional variation reflecting its specific role as an industrial emporium.

The establishment of such an effective and fairly uniform bronze tradition in the Indus communities would not have been possible without the steady and reliable supply of raw materials. It is not difficult to imagine that the well-established trade networks connecting the towns within as well as outside the Indus realm played a key role in the flow of such material resources. In this unique environment, the development of versatile metal intermediaries appropriate for ready transportation must have been necessary. The analytical results presented above strongly suggest that they were produced most frequently in rods, curved or straight, and sometimes in plates. The idea of circulating such intermediaries, both unalloyed and pre-alloyed, ready to be hammered into functional items would be even more advantageous if the raw materials were not available nearby. This possibility was also noted by Hoffman and Miller (2009) who emphasized the role of product intermediaries in the form of ingots or scrap as the primary means of metal acquisition for Indus communities. Little is known of the sources of copper and its alloys for the two Harappan sites under consideration although the famed Khetri belt of Rajasthan might have served as one of the major copper sources while Afghanistan was considered a probable tin source for many Indus sites (Kenoyer and Miller, 1999: 117–118). For most Indus towns with ready access to multipurpose intermediaries circulating through the Indus trade networks, however, the physical distance from the producers would not have mattered much for running their bronze industry.

6. Conclusion

A number of copper-base metal objects of the Mature Harappan context, recovered from the two Indus settlements at Farmana in Haryana and Kuntasi in Gujarat of India, were examined for microstructures and alloy compositions. The metal assemblages from both sites consisted primarily of objects in the form of curved or straight rods and plates, which could be used as product intermediaries. The microstructural data showed that forging was the primary method of fabrication for the absolute majority of those examined. The composition data revealed that arsenic served as the major alloying element in both Farmana and Kuntasi assemblages while tin was added only in some of the Kuntasi objects. Evidence was found that the tin level in the bronze was determined with the arsenic concentration in mind. Zinc was added in five objects (4 from Farmana and 1 from Kuntasi) by approximately 20%. These objects are one of the earliest examples of extant man-made brasses. Lead was also used, but only occasionally and mostly in the few cast products.

Despite the clear difference in the use of tin, the Harappan communities at Farmana and Kuntasi established a similar bronze technology based on forging as the key fabrication method. This dependence on forging was evidently a necessary and effective choice to meet their needs for metal products in the midst of their disadvantageous environment where the raw materials available were predominantly unalloyed or insufficiently alloyed copper. Given the complete absence of evidence for in-site smelting in both Farmana and Kuntasi, the metalworkers must have depended on imports for raw materials. The abundance of rod or plate-type objects in the metal assemblages under consideration indicates that they could have served as a medium for trade, transportation and further processing. The great variation in alloy compositions observed in similar objects such as rings, bangles and rods should then be understood as intended for various consumer needs. The production and circulation of such intermediaries may have been responsible for the uniformity noted in currently available data on Indus bronze objects (Kenoyer and Miller, 1999), i.e., the

dependence on forging for fabrication and the selection of copper alloys with little or limited amounts of tin or arsenic. The extensive trade networks connecting Indus towns may also have played an important role in the establishment of such a uniform technological tradition. One of important questions that may be raised regarding this uniformity is whether it was initiated by people migrating from the central Indus zone to the outer fringes, such as at Farmana and Kuntasi, or by local people adapting themselves to the mainstream technological practices.

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